The Higgs Mass as the Discriminator of Electroweak Models

Marco A. Díaz, Tonnis A. ter Veldhuis and Thomas J. Weiler
Department of Physics & Astronomy
Vanderbilt University
Nashville, TN 37235, USA

ABSTRACT

In the Minimal Supersymmetric Model (MSSM) and the Next to Minimal Supersymmetric Model [(M+1)SSM], an upper bound on the lightest higgs mass can be calculated. On the other hand, vacuum stability implies a lower limit on the mass of the higgs boson in the Standard Model (SM). We find that a gap exists for $m_t \stackrel{>}{\sim} 165$ GeV between the SM and both the MSSM and the (M+1)SSM bounds. Thus, if the new top quark mass measurement by CDF remains valid, a first measurement of the higgs mass will serve to exclude either the SM or the MSSM/(M+1)SSM higgs sectors. In addition, we discuss Supersymmetric Grand Unified Theories, other extentions of the SM, the discovery potential of the lightest higgs, and the assumptions on which our conclusions are based.

PACS numbers: 12.60Fr, 12.60Jv, 12.15Lk, 14.80Cp. 14.80Bn

arXiv:hep-ph/9408319v1 18 Aug 1994

The Achilles' heel of the Standard Model (SM) is the electroweak symmetry–breaking sector. The simplest and most motivated possibilities for this sector are the single higgs doublet of the minimal SM, and the two higgs doublet sector of the Minimal Supersymmetric Standard Model (MSSM). After roughly twenty years of experimental efforts to expose the origin of broken weak symmetry, not a single clue has been found. In particular, the simple SM and MSSM possibilities remain viable but unconfirmed. Recently, hope has risen that a new window to the symmetry–breaking sector may have been found: the CDF experiment at Fermilab has announced [1] the probable discovery of the top quark with mass at 174 ± 16 GeV (very consistent with the SM prediction of $m_t = 164 \pm 25$ GeV inferred from precision electroweak data [2]). This range of m_t values encompasses the electroweak symmetry–breaking scale, defined by the vacuum expectation value (vev) $< 0|\Phi|0 >= v_{SM}/\sqrt{2} = 175$ GeV of the complex higgs field Φ. The fact that the central CDF value is nearly identical to the Φ vev is intriguing, and presumably coincidental. The fact that the eventual true value of m_t will be comparable to the symmetry–breaking scale is fortuitous, for it suggests that the top quark may communicate the secrets of the symmetry–breaking to us either through top properties, or through large quantum corrections to classical physics. In the SM and in supersymmetric (susy) models the main uncertainty in radiative corrections is the value of the top mass. If the CDF announcement is confirmed, this main uncertainty is eliminated. One observation [3] which we quantify in this Letter is the following: inputing the CDF value for the top mass into quantum loop corrections for the symmetry– breaking higgs sector leads to mutually exclusive, reliable bounds on the SM higgs mass and on the lightest MSSM higgs mass. From this we infer that *if the CDF value for m_t is verified in the 1994–95 data run, then the first higgs mass measurement will rule out one of the two main contenders (SM vs. MSSM) for <u>the</u> electroweak theory, independent of any other measurement.*

Another point deserves emphasis. It is known that the Feynman rules connecting the lightest higgs in the MSSM to ordinary matter become exactly the SM Feynman rules, in the limit where the "other" higgs masses (these are m_A, m_H, and $m_{H^\pm}$, found in any two-higgs-doublet models) are taken to infinity [4]. When the masses are taken large compared to M_Z, of the order of a TeV for example, the lightest MSSM higgs behaves very much like the SM higgs in its production channels and decay modes [5]. Furthermore, the mass of the lightest MSSM higgs rises toward its upper bound as the "other" higgs masses are increased. Thus, for masses in the region where the SM lower bound and the MSSM upper bound overlap, the SM higgs and the lightest MSSM higgs may not be distinguishable by branching ratio or width measurements. Only if the two bounds are separated by a gap is this ambiguity avoided. Thus, *there may be no discernible difference between the lightest MSSM higgs and the SM higgs, except for their allowed mass values.* The gap develops with increasing m_t because the MSSM higgs self–coupling is constrained, a vestige of the underlying supersymmetry, and thus requires the MSSM higgs to be light, whereas SM vacuum stability requires the SM higgs to be heavy. We demonstrate the onset of the mass gap in Fig. 1.

Recently it has been shown that when the newly reported value of the top mass is input into the effective potential for the SM higgs field, the broken–symmetry potential minimum

is stable [1] only if the SM higgs mass satisfies the lower bound constraint [6]:

$$m_H > 132 + 2.2(m_t - 170) - 4.5(\frac{\alpha_s - 0.117}{0.007}),\tag{1}$$

valid for a top mass in the range 160 to 190 GeV. In this equation, mass units are in GeV, and α_s is the strong coupling constant at the scale of the Z mass. This equation is the result of RGE–improved two–loop calculations, and includes radiative corrections to the higgs and top masses. It is reliable [2], and accurate to 1 GeV in the top mass, and 2 GeV in the higgs mass [6].

It has been known for some time [8] that the SM lower bound rises rapidly as the value of the top mass increases through M_Z; below M_Z the bound is of order of the Linde–Weinberg value, ~ 7 GeV [9]. So what is new here is the inference from the large reported value for m_t that the SM higgs lower mass bound dramatically exceeds 100 GeV! The D0 collaboration has used its nonobservation of top candidates to report a 95% confidence level lower bound on the top mass of 131 GeV [10]. Thus, the D0 lower bound, and the CDF mass value including 1σ allowances are, respectively, 131, 158, 174, and 190 GeV. Inputing these top mass values into Eq. (1) and the equivalent for the lower range of m_t [6] with $\alpha_s = 0.117$ then yields SM higgs mass lower bounds of 60, 106, 140, and 176 GeV, respectively.

This lower limit on the SM higgs from the vacuum stability argument is a significant phenomenological constraint, and it rises linearly with m_t, for $m_t \gtrsim 100$ GeV. On the other hand, the upper limit on the lightest MSSM higgs rises quadratically with m_t, also for $m_t \gtrsim 100$ GeV. In fact, *the radiatively corrected observable most sensitive to the value of the top mass is the mass of this lightest higgs particle in susy models* [11]: for large top mass, the top and scalar–top ($\tilde{t}$) loops dominate all other loop corrections, and *the light higgs mass–squared grows as* $m_t^4 \ln(m_{\tilde{t}}/m_t)$ [3] . Thus, for very heavy m_t, the two bounds will inevitably overlap. Also, for relatively light m_t the bounds may overlap; e.g. we have just seen that the SM lower bound is 60 GeV for $m_t = 131$ GeV, whereas for large or small $\tan\beta$ the MSSM upper bound is at least the Z mass. However, for m_t around the value reported by the CDF collaboration, we demonstrate by careful calculation that there is a gap between the SM higgs mass lower bound and the MSSM upper bound. Thus, the first measurement of the lightest higgs mass will serve to exclude either the SM higgs sector, or the MSSM higgs sector!

Since vacuum stability of the SM first breaks down for scalar field fluctuations on the order of $10^6 - 10^{10}$ GeV [6], an implicit assumption in this SM bound is no new physics below 10^{10} GeV. In particular, the stability bound, calculated with perturbation theory, is not valid if there is a non–perturbatively large value for the higgs self–coupling λ below $\sim 10^{10}$ GeV.

---

[1] If the universe is allowed to reside in an unstable minimum, then a similar, but slightly weaker (by $\gtrsim 5$ GeV for heavy m_t [6]) bound results [7].

[2] If we use the generous value $\alpha_s = 0.129$, the lower bound on the SM higgs mass decreases by about 8 GeV for $m_t > 160$ GeV. A decrease of even this magnitude in the SM lower bound is compensated by the decrease in the MSSM upper bound due to two-loop contributions not included in our calculations, but discussed in the text.

[3] Note that the correction grows logarithmically as $m_{\tilde{t}}$ gets heavy, rather than decoupling! For heavy $m_{\tilde{t}}$ the large logarithms can be summed to all orders in perturbation theory using renormalization group techniques. Interestingly, the effect is to lower the MSSM upper bound [12].

However, if there is a non–perturbatively large value for λ below 10^{10} GeV, then there will be a Landau pole near or below 10^{10} GeV, which in turn implies a *triviality <u>lower</u> bound* on the SM higgs mass of about 210 GeV. A derivation and discussion of this triviality lower bound, as well as further details related to the matters of this Letter, are given in [13]. An immediate consequence is: *assuming no new fields with mass scales below 10^{10} GeV, either the perturbative stability bound is valid for the SM higgs, or the non–perturbative triviality lower bound is valid.* The stability bound is the less restrictive, and we assume it in the subsequent sections of this paper.

Turning now to the MSSM model, we calculate the one-loop corrected lightest MSSM higgs mass, m_h [14], including the full one–loop corrections from the top/bottom quarks and squarks, and the leading–log corrections from the remaining fields (charginos, neutralinos, gauge bosons, and higgs bosons). As advertised earlier, the mass corrections are sizeable [4]. Recently, full one–loop corrections from all particles [16] have been calculated. Since the dominant corrections are due to the heavy quarks and squarks, full one–loop corrections from charginos, neutralinos, gauge and higgs bosons are well approximated by their leading logarithm terms used here. Two–loop corrections have recently been calculated also [17], for the limit where the ratio of the vacuum expectation values $\tan\beta \to \infty$. Keeping only the leading m_t terms, these corrections have been extrapolated to all $\tan\beta$. The graphical result in ref. [17] shows a <u>lowering</u> of the MSSM upper bound by several GeV [5]. From this work [17], we estimate the gap to be wider by several GeV than the one–loop separation we show in our figure. This widening further enables a higgs mass measurement to distinguish the SM and MSSM models.

The lightest higgs mass as a function of $\tan\beta$ is shown in Fig. 1. For the case $\tan\beta \sim 1$, the SM lower bound and the MSSM upper bound are already non–overlapping at $m_t = 131$ GeV. However, for larger $\tan\beta$ values, the overlap persists until $m_t \stackrel{>}{\sim} 165$ GeV. For the preferred CDF value of $m_t = 174$GeV, the gap is present for all $\tan\beta$, allowing discrimination between the SM and the MSSM based on the lightest higgs mass alone. At $m_t = 190$ GeV the gap is still widening, showing no signs of the eventual gap–closure at still higher m_t. It is reassuring that the upper bounds in the region of acceptable $\tan\beta$ are similar for small and large squark mixing.

The MSSM can be extended in a straightforward fashion by adding an $SU(2)$ singlet S with vanishing hypercharge to the theory [19]. As a consequence, this (M+1)SSM model contains an additional scalar, pseudoscalar, and neutralino. A tree–level analysis of the eigenvalues of the scalar mass matrix yields an upper bound on the mass of the lightest higgs boson:

$$m_h^2 \leq M_Z^2 \left\{ \cos^2 2\beta + 2\frac{\lambda^2}{g_1^2 + g_2^2} \sin^2 2\beta \right\}. \tag{2}$$

The new higgs self coupling λ is *a priori* free, and so the second term may <u>considerably</u> weaken the upper bound [20, 21]. However, there are two cases where the bound will suffer

---

[4] Notice that the lightest higgs mass, bounded at tree–level by $m_h \leq |\cos(2\beta)| M_Z$, vanishes at tree level if $\tan\beta = 1$. However, radiative corrections so strongly modify this tree level prediction that the $\tan\beta = 1$ scenario remains viable [15].

[5]In ref. [18] were found small two-loop contributions of the order m_t^6; however, the QCD two-loop contributions found in ref. [17] are of order $\alpha_s^2 m_t^4$, and dominate the previous ones. The net effect is to lower the higgs mass bound.

m_t		131	158	174	190
SM	$m_h >$	60	106	140	176
MSSM	$m_h <$	104	119	130	143
(M+1)SSM	$m_h <$	136	129	128	133

Table 1: The SM lower bound and the MSSM and (M+1)SSM upper bounds on the higgs boson mass m_h for various values of the top quark mass m_t.

only a minor adjustment. The first is the large $\tan\beta$ scenario, where $\cos^2 2\beta$ is necessarily $\gg \sin^2 2\beta$. The second is when the theory is embedded into a GUT; even if λ assumes a high value at the GUT scale, the nature of the renormalization group equations is such that its evolved value at the susy–breaking scale is a rather low, pseudo–fixed point. Under the assumption that all coupling constants remain perturbative up to the GUT scale, it is therefore possible to calculate a maximum value for the mass of the lightest higgs boson [20, 21]. The higgs mass upper bound depends on the value of the top yukawa at the GUT scale through the renormalization group equations.

In Fig. 1 we show the maximum value of the higgs boson mass as a function of $\tan\beta$ for the chosen values of the top quark mass m_t. The bounds are quite insensitive to the choice of M_{SUSY}, increasing very slowly as M_{SUSY} increases [20]. It is revealed that for low values of the top quark mass ($\sim M_Z$), the mass upper bound on the higgs boson in the (M+1)SSM will be substantially higher than in the MSSM at $\tan\beta \stackrel{<}{\sim}$ a few. However, for a larger top quark mass the difference between the MSSM and (M+1)SSM upper bounds diminishes. There is a minimum allowed $\tan\beta$ in the (M+1)SSM, implied by the top yukawa pseudo–fixed–point. The minimum rises with m_t, and is evident in the figure. The (M+1)SSM and MSSM bounds are very similar at $\tan\beta \stackrel{>}{\sim} 6$ (the only viable region in the (M+1)SSM model for m_t at or above the CDF value). Since the (M+1)SSM model was originally constructed to test the robustness of the MSSM, it is gratifying that the two models show a very similar upper bound.

The results for more complicated extensions of the minimal susy model tend to be similar [22]. In general, the mass of the lightest higgs boson at tree level is limited by M_Z times a factor proportional to the dimensionless coupling constants in the higgs sector. The requirement of perturbative unification restricts the value of these coupling constants at the electroweak scale, and the maximum value of the lightest higgs boson mass is therefore never much larger than M_Z.

We have seen that the SM, MSSM, and the (M+1)SSM electroweak models can be disfavored or ruled out by a measurement of m_h; and that a "forbidden" mass gap exists for these models if $m_t \stackrel{>}{\sim} 165$ GeV. A summary of these mass bounds [6] is provided in table 1, for four possible m_t values. However, some other models do not tightly constrain the lightest higgs mass. Examples of such models are the SM without a desert [24], non–minimal SUSY

---

[6] In constructing this table, we have taken the values of the MSSM higgs upper bound without considering the region $\tan\beta \ll 1$. Large radiative corrections appear at $\tan\beta \ll 1$ because the value of the top yukawa coupling is extrapolated beyond what is perturbatively valid; the result is suspect. The argument of perturbative validity argues against this small $\tan\beta$ region [23].

with unconstrained higgs self–coupling, and low energy effective models of strongly coupled theories [25]. These models cannot be ruled out by a single higgs mass measurement.

Many supersymmetric grand–unified theories (susy GUTs) reduce at low energies to the MSSM with additional constraints on the parameters. Accordingly, the upper limit on m_h in such susy GUTs is in general <u>more</u> <u>restrictive</u> than the bound presented here. The assumption of the pseudo–fixed–point solution for the top mass is an attractive example because the apparent CDF top mass value is within the estimated range of the pseudo–fixed–point [26]. With the additional assumptions that the electroweak symmetry is radiatively broken and that the low energy MSSM spectrum is defined by a small number of parameters at the GUT scale, two compact, disparate allowed ranges for $\tan\beta$ emerge: $1.0 \leq \tan\beta \leq 1.4$ [27], and a large $\tan\beta$ solution $\sim m_t/m_b$, disfavored by proton stability arguments [28]. In fact, a highly constrained low $\tan\beta$ region ~ 1 and high $\tan\beta$ region $\overset{>}{\sim}$ 40–70 also emerge when bottom–τ yukawa unification at the GUT scale is imposed on the radiatively broken model [29]. The small $\tan\beta$ restriction results when the top mass, but not the bottom mass, is assigned to its pseudo–fixed–point. Resulting mass bounds in the literature are basically our bound in Fig. 1 for $\tan\beta \sim 1-3$. The net effect of the yukawa–unification constraint in susy GUTs is necessarily to widen the mass gap between the light higgs MSSM and the heavier higgs SM, thus strengthening the potential for experiment to distinguish the models.

We end with conclusions on detectability of the lightest higgs [30, 31]. If $m_t \sim 131$ GeV, then the SM higgs mass lower bound from vacuum stability is 60 GeV; a SM mass up to (80,105) GeV is detectable at (LEP178,LEP200), and a SM mass up to 130 GeV is detectable at a High Luminosity Di Tevatron (HLDT) [31]; the MSSM h^0 is certainly detectable at LEP178 for $\tan\beta \sim 1$–2, and certainly detectable at LEP200 for all $\tan\beta$. If $m_t \sim 174$ GeV, then the SM higgs is above 140 GeV, out of reach for LEPII and the HLDT; the MSSM higgs is certainly detectable at LEP200 if $\tan\beta \sim 1$–2. Conclusions for $m_t = 158$ and 190 geV can be inferred after reference to Table 1. It is interesting that the h^0 mass range is most accessible to experiment if $\tan\beta \sim 1$–3, just the parameter range favored by susy GUTs.

We repeat that the lightest MSSM higgs is guaranteed detectable at LEP230; and that the lightest (M+1)SSM higgs and MSSM higgs are guaranteed detectable at a NLC300 and at the LHC. Since there is no lower bound on the lightest MSSM higgs mass other than the experimental bound, the MSSM h^0 is possibly detectable even at LEP178 for all $\tan\beta$, but there is no guarantee. The SM higgs is guaranteed detectable only at the LHC; if $m_t \sim 174$ GeV, then the SM higgs will not be produced until the LHC or NLC is available. Thus, one simple conclusion is that LEPII has a tremendous potential to distinguish MSSM and (M+1)SSM symmetry breaking from SM symmetry breaking.

In conclusion, we have shown that for a top quark mass ~ 174 GeV, as reported by CDF, a gap exists between the SM higgs mass ($\overset{>}{\sim}$ 140 GeV) and the lightest MSSM higgs mass ($\overset{<}{\sim}$ 130 GeV). Thus, the first higgs mass measurement will eliminate one of these popular models. Most of the MSSM mass range is accessible to LEPII. If a higgs is discovered at LEPII, the SM higgs sector is ruled out. We remind the reader that our conclusions regarding the SM assume a desert up to (at least) 10^{10} GeV. For the (M+1)SSM with the assumption of perturbative unification, conclusions remain the same as for the MSSM.

Acknowledgements:

References

[1] F. Abe et al. CDF Collaboration, Fermilab Pub–94/097–E, (1994).

[2] The LEP Electroweak Working Group (Aleph, Delphi, L3, Opal), CERN preprint PPE/93–157 (1993).

[3] N. V. Krasnikov and S. Pokorski, *Phys. Lett.* **B288**, 184 (1992).

[4] *The Higgs Hunter's Guide*, J. F. Gunion, H. E. Haber, G. L. Kane, and S. Dawson, Addison-Wesley, Redwood City, CA (1990).

[5] P. H. Chankowski, S. Pokorski, and J. Rosiek, *Phys. Lett.* **B281**,100 (1992).

[6] M. Sher, Phys. Lett. B317, 159 (1993), and Addendum (1994) hep-ph #9404347; see also C. Ford, D. R. T. Jones, P. W. Stevenson and M. B. Einhorn, Nucl. Phys. B395, 62 (1993).

[7] P. Arnold and M. Vokos, Phys. Rev. D44, 3620 (1991); G. W. Anderson, Phys. Lett. B243, 265 (1990).

[8] Two excellent reviews of the effective potential physics and bounds are: M. Sher, Phys. Rep. 179, 273 (1989); and H. E. Haber, *Lectures on Electroweak Symmetry Breaking*, TASI, Boulder, CO (1990).

[9] A. Linde, Phys. Lett. B62, 435 (1976); S. Weinberg, Phys. Rev. Lett. 36, 294 (1976).

[10] S. Abachi at al. Phys. Rev. Lett. 72, 2138 (1994).

[11] H.E. Haber and R. Hempfling, *Phys. Rev. Lett.* **66**, 1815 (1991); Y. Okada, M. Yamaguchi and T. Yanagida, *Prog. Theor. Phys.* **85**, 1 (1991); J. Ellis, G. Ridolfi and F. Zwirner, *Phys. Lett.* **B257**, 83 (1991).

[12] H.E. Haber and R. Hempfling, *Phys. Rev. D* **48**, 4280 (1993).

[13] Marco A. Díaz, Tonnis A. ter Veldhuis, and Thomas J. Weiler, Vanderbilt University preprint VAND–TH–94–14 and hep–ph #9407357 (1994).

[14] M. A. Díaz, preprint VAND–TH–94–16, in progress.

[15] M.A. Díaz and H.E. Haber, *Phys. Rev. D* **46**, 3086 (1992).

[16] P. H. Chankowski, S. Pokorski and J. Rosziek, MPI–Ph/92–116, (1992).

[17] R. Hempfling and A. H. Hoang, preprint DESY 93–162, Nov., 1993.

[18] J. R. Espinosa and M. Quiros, *Phys. Lett.* **B266**, 389 (1991).

[19] J. Ellis, J.F. Gunion, H.E. Haber, L. Roszkowski and F. Zwirner, *Phys. Rev.* **D39**, 844 (1989); M. Drees, *Int. J. Mod. Phys.* **A4**, 3635 (1989).

[20] W.T.A. ter Veldhuis, Purdue Preprint PURD-TH-92-11.

[21] J.R. Espinosa and M. Quirós, Proc. of the Int. Conf on High Energy Physics, Dallas TX (1992); T. Elliot, S.F. King and P.L. White, *Phys. Lett.* **B305**, 71 (1993); P. Binetruy and C. A. Savoy, *Phys. Lett.* **B277**, 453 (1992).

[22] R. Flores and M. Sher, *Ann. Phys.* **148**, 95 (1983); M. Dres, *Intern. J. Mod. Phys.* **A4**, 3635 (1989); G.L. Kane, C. Kolda and J.D. Wells, *Phys. Rev. Lett.* **70** 2686 (1993); J.R. Espinosa and M. Quiros, *Phys. Lett.* **B302** 51 (1993); D. Comelli and E. Verzegnassi, *Phys. Rev.* **D47** 764 (1993).

[23] V. Barger, J.L. Hewett, and R.J.N. Phillips, *Phys. Rev. D* **41**, 3421 (1990); see also M.A. Díaz and H.E. Haber, *Phys. Rev. D* **45**, 4246 (1992).

[24] U. Ellwanger and M. Lindner, *Phys. Lett.* **B301**, 365 (1993); M. Lindner, M. Sher and H. Zaglauer, *Phys. Lett.* **B228**, 139 (1989).

[25] S. Ferrara, A. Masiero and M.Poratti, *Phys. Lett.* **B301** (1993) 358; S. Ferrara and A. Masiero, CERN TH-6846-93; S. Ferrara, A. Masiero, M. Porrati and R. Stora, CERN TH-6845-93; T.E. Clark and W.T.A. ter Veldhuis, PURD-TH-93-14; W.T.A. ter Veld- huis, VAND-TH-94-10; K.J. Barnes, D.A. Ross and R.D. Simmons, SHEP 93/94-12 (1994).

[26] W. A. Bardeen, M. Carena, S. Pokorski, and C. E. M. Wagner, *Phys. Lett.* **B320**, 110 (1994); M. Carena and C.E.M. Wagner, CERN preprint TH.7320/94 and hep–ph #9407208; CERN preprint TH.7393/93 and hep–ph #9408253.

[27] V. A. Bednyakov, W. de Boer, and S. G. Kovalenko, hep–ph #9406419, June 1994.

[28] R. Arnowitt and P. Nath, *Phys. Rev. Lett.* **69**, 1014 (1992); *Phys. Lett.* **B287**, 89 (1992), and **B289**, 368 (1992).

[29] V. Barger, M. S. Berger, P. Ohmann, and R. J. N. Phillips, *Phys. Lett.* **B314**, 351 (1993); M. Carena and C. E. M. Wagner, CERN–TH.7320/94, and references therein; P. Langacker and N. Polonsky, *Phys. Rev.* **D49**, 1454 (1994); UPR–0594–T (1994); N. Polonsky, UPR–0595T, (1994); M. Carena, M. Olechowski, S. Pokorski, and C. E. M. Wagner, *Nucl. Phys.* **B419**, 213 (1994); C. Kolda, L. Roszkowski, and J. D. Wells, and G. L. Kane, UM–TH–94–03, and references therein.

[30] J. F. Gunion, "Searching for the Higgs Boson(s)", to appear in Proc. of the Zeuthen Workshop — LEP200 and Beyond, Teupitz/Brandenburg, Germany, 10–15 April, 1994, eds. T Riemann and J Blumlein; and refs. therein.

[31] S. Mrenna and G. L. Kane, Caltech preprint CIT 68–1938 and hep–ph #9406337.

Figure Caption:
Fig. 1. Higgs mass as a function of $\tan\beta$ for two different values of the top quark mass (a) $m_t = 174$ and (b) $m_t = 131$ GeV. We show the SM lower bound (dotdash), the (M+1)SSM upper bound (solid) with a GUT scale given by 10^{16} GeV, and the MSSM upper bound (dashes). In the MSSM case curves are shown for two different choices of the squark mixing parameters: no squark mixing ($\mu = A = 0$) and maximal mixing ($\mu = A = 1$ TeV). The first choice is the one where the higgs mass approaches asymptotically to a constant as $\tan\beta$ increases. In all cases, every superparticle and higgs beyond the lightest are assumed to have a mass of the order of 1 TeV.

This figure "fig1-1.png" is available in "png" format from:

http://arXiv.org/ps/hep-ph/9408319v1

m_h (GeV)

tan β

gap

(b) m_t=131 GeV
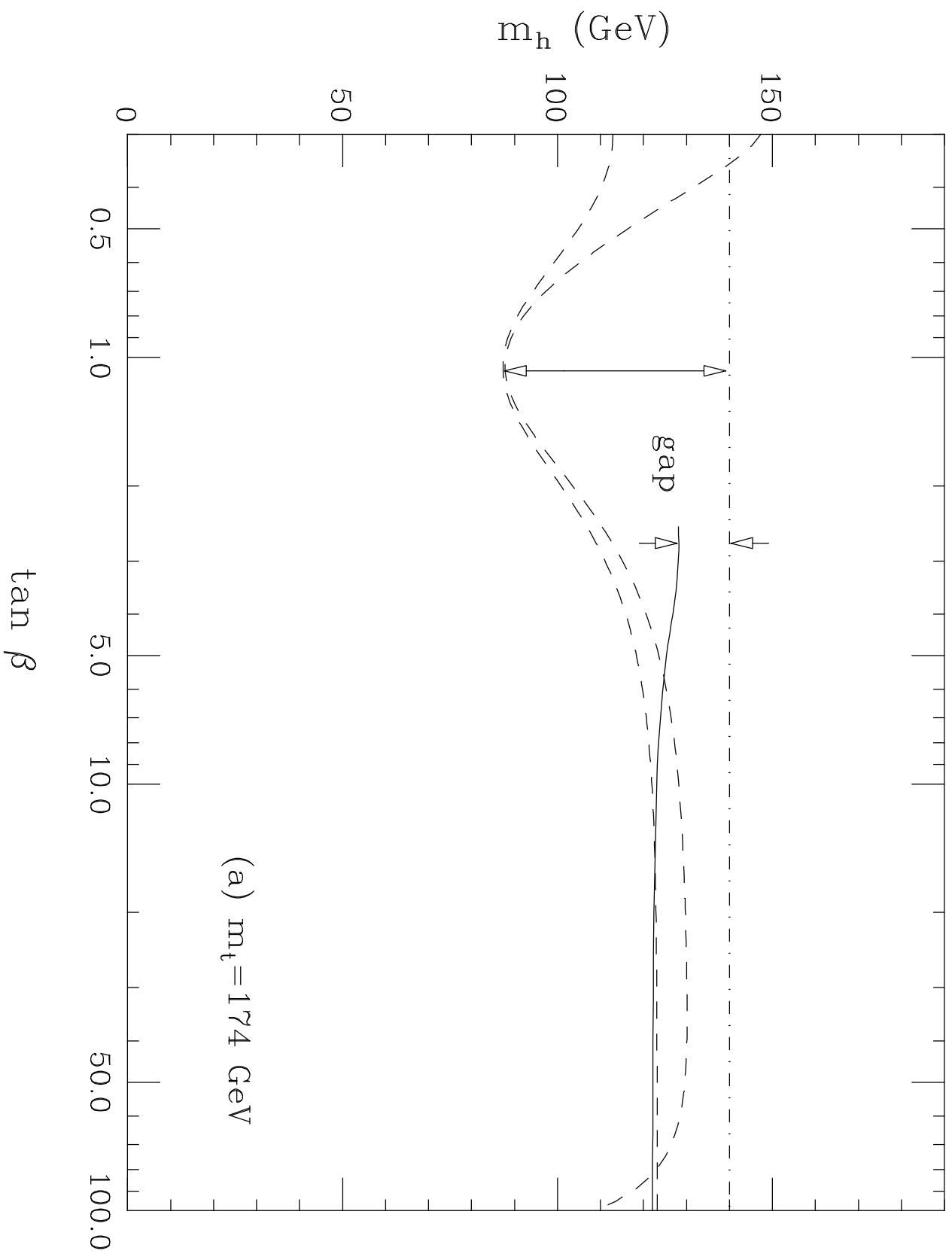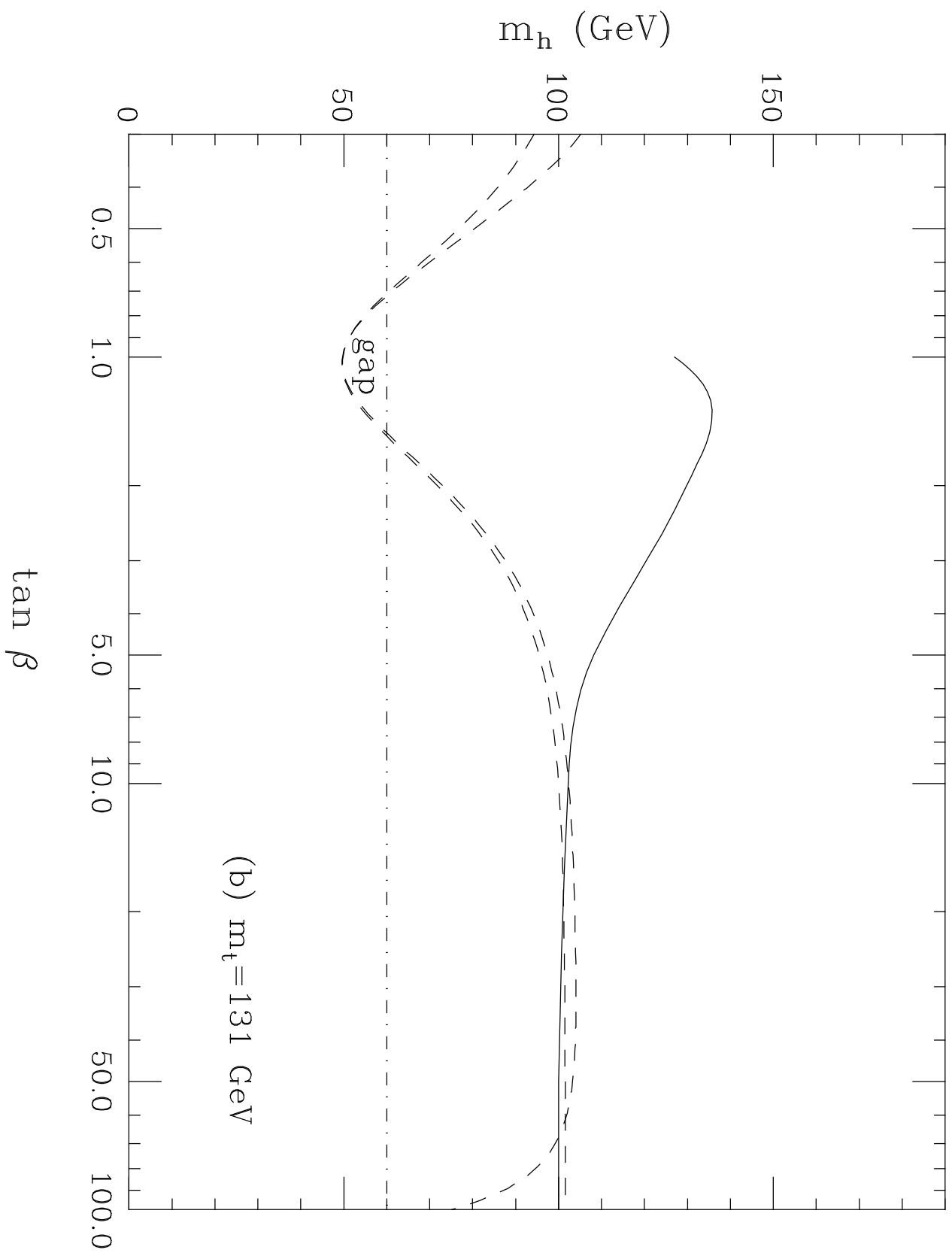
This figure "fig2-1.png" is available in "png" format from:

http://arXiv.org/ps/hep-ph/9408319v1